Journal of Forensic and Legal Medicine 20 (2013) 264–269

Contents lists available at SciVerse ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/locate/jflm

Original communication

Acoustic levels of heavy truck tire ruptures

Matthew Wood M.S. *, William Woodruff Ph.D.

InSciTech Inc., 185 Berry St., Suite 3700, San Francisco, CA 94107, USA

ARTICLE INFO

Article history:
Received 26 March 2012
Received in revised form
16 July 2012
Accepted 7 September 2012
Available online 24 October 2012

Keywords:
Acoustic
Truck
Tire
Ruptures
Explosions
Failure

ABSTRACT

Transportation vehicles, whether they are passenger vehicles or heavy trucks and transport vehicles, rely upon rubber tires to negotiate the roadways and surfaces on which they are driven. These tires have the potential of sudden rupture resulting from various causes including but not limited to over-pressurization, sidewall failures, or punctures from roadway debris. These rupture events can and do occur while the vehicles are stationary (e.g., during servicing) or are being driven, and often occur without notice. While the phenomenon of sudden tire failure has been documented for several decades, the potential bodily injury which can occur when an individual is in close proximity to such a sudden rupture has only more recently been documented. Aside from anecdotal mention in case studies, there has been little quantitative information available on the acoustic levels during these failures. Our study provides measured acoustic levels as a function of distance for such catastrophic tire failures.

1. Introduction

Heavy trucks and transport vehicles comprise roughly 45 percent of all vehicles on the roadway (FHWA, 2009).[6] These vehicles may be tractor–trailer combinations, delivery vehicles, service vehicles, or farm vehicles, all with Gross Axle Weight Ratings (GAWRs) much higher than those of passenger vehicles. The higher load bearing capacity of these vehicles necessitates that the tires support higher loads as well. Recommended tire inflation pressures in passenger vehicles are in the 32–36 psi range (Continental Tire, 2009–2010).[5] In comparison, inflation pressures of heavy truck tires are typically between 70 and 120 psi (Sumitomo Tires, 2008).[13]

The higher inflation pressures of heavy truck tires represent an increased potential for injury during tire rupture simply from the presence of higher levels of stored energy contained within the tire and wheel assembly. Tires may fail for several reasons, but tire blowouts are the most common comprising 40 percent of tire failures on heavy vehicles (Bareket, Blower, & MacAdam, 2000).[3] One way for blowouts to occur is continued vehicle operation while tires are below the recommended inflation pressure or vehicles are over their recommended load (Rohlwing, 2000).[12] When tire pressures are allowed to fall below the recommended pressures, tire sidewall heights decrease creating cyclical loading of the steel body cords of the structure of the tire. This circumstance can lead to what is known as a "zipper rupture" (Rohlwing, 2000)[12] in which a section of the steel cords of the tire suddenly fails. This may happen when additional air is added to the tire while the vehicle is being serviced, or while the vehicle is in operation (e.g., if the vehicle drives over roadway debris (Clarke, 1972)).[4]

The fact that sudden tire failures occur is known to drivers of heavy vehicles and those within the tire- and tire-servicing industries. The potentially dangerous nature of these events and the chance of catastrophic injury in these non-collision accidents has been recognized for decades as evidenced by the presence of tire inflation cages and guards as early as 1946 (see Fig. 1).

The literature in this area has been largely focused on contact injuries sustained from projectiles created in these events. Consequently, these occurrences are sometimes likened to blasts or explosion events. There is some mention of primary blast injuries involving the human ear (Murty, 2009),[9] but no documentation of the acoustic levels which can occur during a sudden tire rupture. The primary safety practices in the literature for tire inflation and

* Corresponding author. 5400 Laurel Springs Parkway #708, Suwanee, GA 30024, USA. Tel.: +1 770 886 3207.
E-mail addresses: mwood@inscitech.com (M. Wood), woodruff@inscitech.com (W. Woodruff).

1752-928X/$ – see front matter
http://dx.doi.org/10.1016/j.jflm.2012.09.012

installation for heavy vehicle tires recommend wearing protective eyewear, clothing, and/or standing to the side of the center of the wheel and tire assembly (OSHA, 2003).[10] Of the service literature reviewed only one listed hearing protection as recommended safety material to be worn by the operator only (ARI Hetra).[2] To understand the phenomenon better, in the current paper, catastrophic tire ruptures were induced in heavy truck tires and the acoustic levels of the resulting failures were measured.

2. Method

A test setup was created in order to simulate a puncture failure caused by roadway debris. A test structure was built by affixing a 4′ × 8′ × 1/2″ piece of plywood to a single 8′ × 12″ × 6″ solid wood beam (Fig. 2). A 1″ hole was drilled at a 45° angle through the beam in order to allow for a striking object to pass though. The striking object used was a concrete chisel tool intended for use as a pneumatic drill tip attachment. The chisel tip was filed to a sharp edge to facilitate the ease of puncturing the tire sidewall. The end of the chisel was then placed into the open end of a 10-foot section of 3/4″ black iron pipe used in common plumbing applications. This pipe was routed through the drilled hole in the wooden beam and connected to two additional ten-foot sections of pipe. This provided a safe distance for the experimenter to be away from the tire while it was being struck by the chisel tip. Two Rion NL-31 Sound Level Meters were placed 4 feet and 8 feet from the tip of the chisel edge (Fig. 2). The meters were placed at different distances to quantify the acoustic drop-off in the readings as a function of distance. The sound level meters were set to record at a rate of 10 Hz and the frequency weighting during recording was A-weighting. Both sound level meters were fitted with a windscreen to reduce any other external sounds at the microphone.

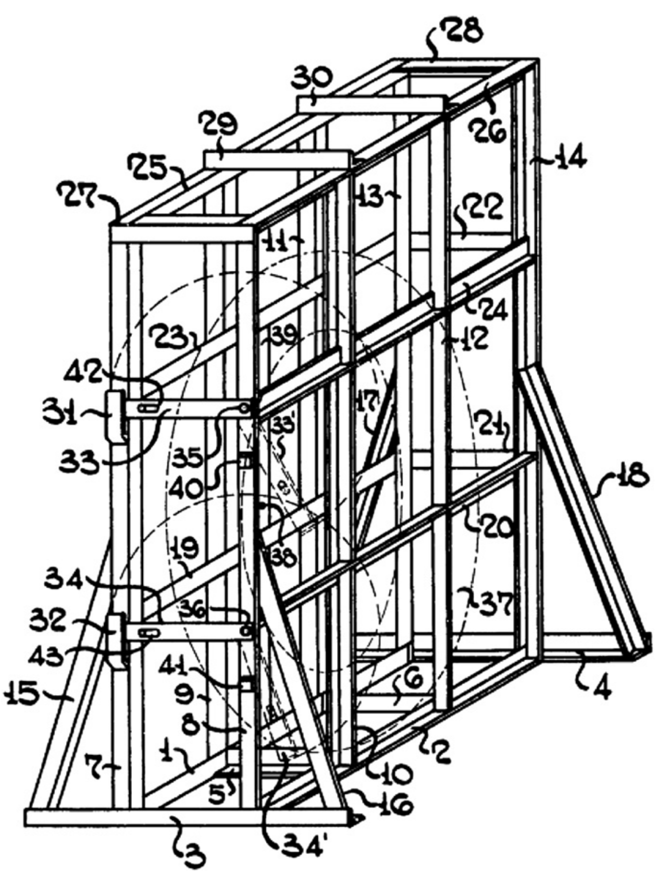


Fig. 1. Tire inflation guard – U.S. Patent 2407049.

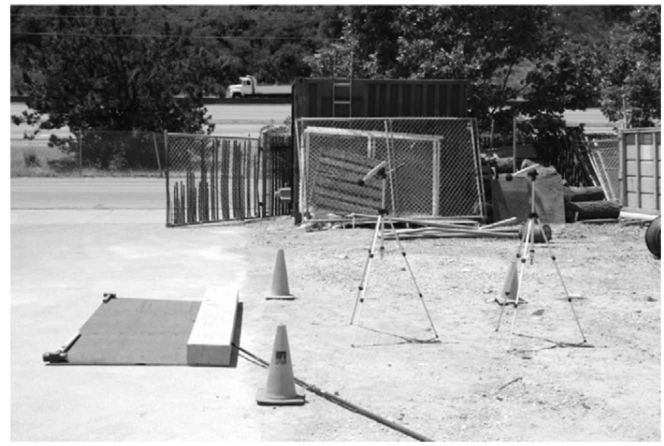


Fig. 2. Overall test setup with roadway mockup, striking object, and sound level meters.

The exemplar vehicle used in these tests was a refuse vehicle with an unladen weight of 55,000 lbs, and was fitted with tires compliant with the recommended vehicle specifications (Diesel Truck Index, 1985).[14] The tires used in the testing were 315/80 R22.5 tubeless steel radials inflated to 100 psi for the tests. The vehicle was positioned so that the axle of the tire to be punctured was directly in line with the striking chisel tip. Two separate tests were conducted: the right-side outboard tire of axle 2 was punctured during the first test and the right-side outboard tire of axle 3 was punctured during the second test. A video camera was positioned parallel to the right side of the vehicle to record the tests.

3. Results

The peak acoustic values measured in the first test were 130.1 dB at the distance of 4 feet from the tire and 124.8 dB at 8 feet from the tire. A plot of the measured data from Test #1 is presented in Fig. 3.

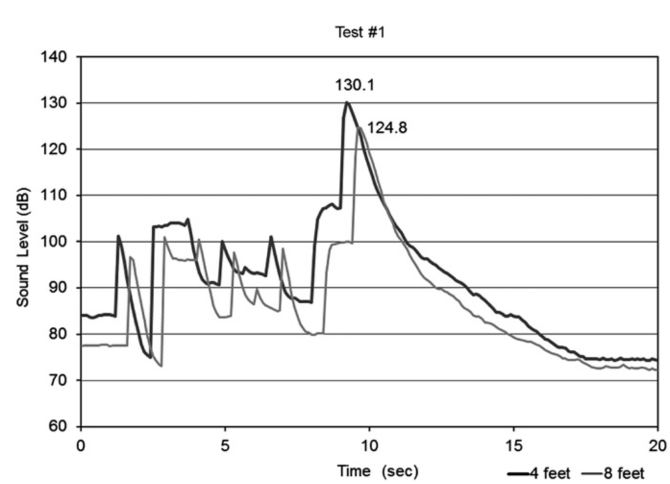


Fig. 3. Sound level plots for Test #1 at measured distances of 4 feet and 8 feet.

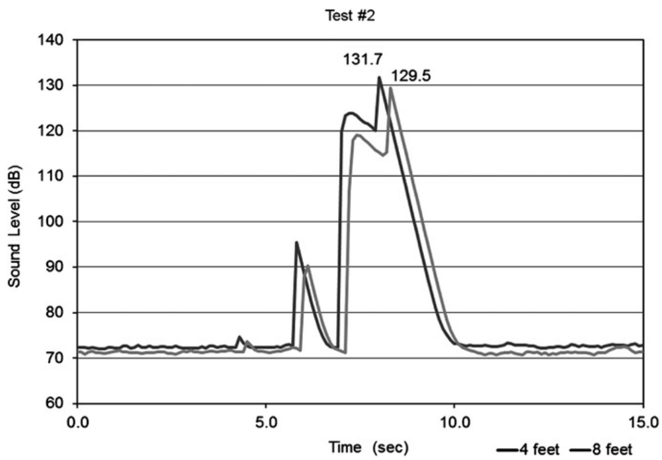


Fig. 4. Sound level plots for Test #2 at measured distances of 4 feet and 8 feet.

The peak values measured in the second test were 131.7 dB at the distance of 4 feet from the tire and 129.5 dB at 8 feet from the tire. A plot of the measured data from Test #2 is presented in Fig. 4.

4. Discussion

These test results present a valuable first insight at quantifying the sound energy levels involved with these violent events. In the first test, the impacting blade partially cut into the tire tread which provided more resistance to the cutting force of the blade and resulted in the air pressure being dissipated over a longer period of time than in the second test. During the second test the cutting edge was aligned more with the sidewall of the tire and resulted in a “zipper” type of failure (Appendix B). Frame by frame images from the video recorded during this event are presented in Appendix C. The results of Test #1 demonstrate that the measured readings follow the inverse distance law for sound:

$$\Delta P = 10\log(I_1/I_2)$$

$$I = 1/d^2$$

$$P_2 = P_1 - 10\log(D_2/D_1)^2 = P_1 - 20\log(D_2/D_1)$$

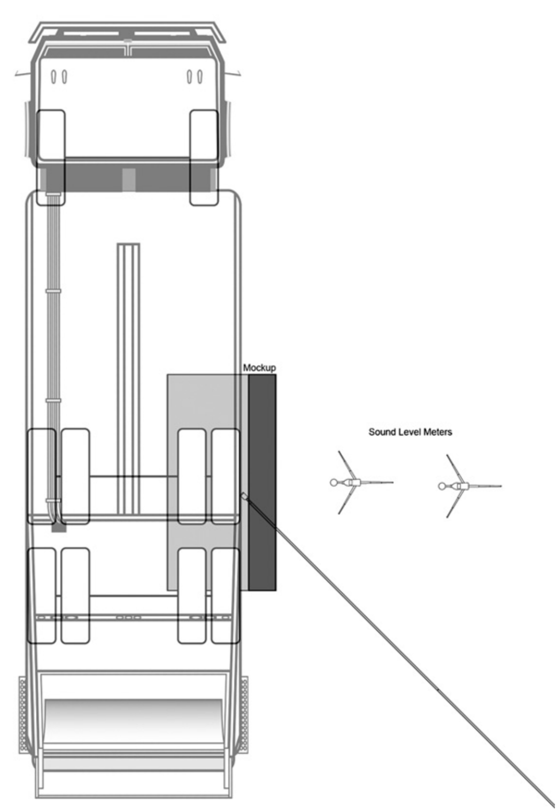
In the above equations the sound intensity is represented by I (watt/m^2), P is the sound pressure level (dB), and D represents the distance from sound source (m). From the equations above one would expect to see a sound level drop of roughly 6 dB for a doubling in the distance from the source of the sound event. This was, however, not the case for the second test in which the measured difference between the two maximum values was 2.2 dB. One possible explanation for this would be the separation of the wood beam from the base which might have slightly reduced the higher sound levels of this event. The two organizations with published recommended levels of noise exposure are the Occupational Safety and Health Administration – OSHA, and the National Institute for Occupational Safety and Health – NIOSH. The first recommends that exposure to blast or impulse noise should not exceed a peak value of 140 dB (OSHA, 2005)[11] and the second (NIOSH, 1998)[15] states that exposure from 130 to 140 dB shall not equal or exceed a time duration of one second. It also sets an upper bound on impulsive noise at 140 dB as well. This would suggest that the generally suggested range of sound exposure to the unprotected ear is 130–140 dB, of which the values from our study fall within. Using the sound pressure level of 120–140 dB as the human threshold for pain (NIOSH, 1996),[16] and the inverse sound law above would allow for the calculation of a safe distances from these events. In this case, an individual without ear protection would need to be 15 feet away to fall below this range. Although these events can occur while pedestrians and members of the general public are involved, the literature suggests that the population of people most affected by these types of events are mechanics or individuals involved with tire installation or vehicle maintenance. However, most tire installations requiring tire cages do not require hearing protection (ARI Hetra).[2] Our initial tests provide preliminary data for the sound levels involved in these events. Further testing is needed using a wider range of tire pressures, tire sizes, and failure modes to obtain a better understanding of the acoustic levels and potential harm associated with these catastrophic failures.

Ethical approval
None.

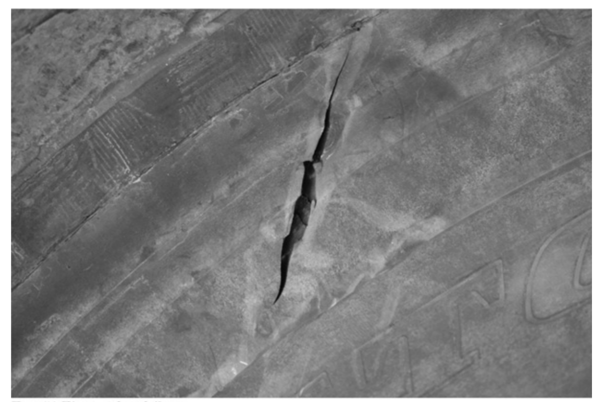
Funding
None.

Conflict of interest
None declared.

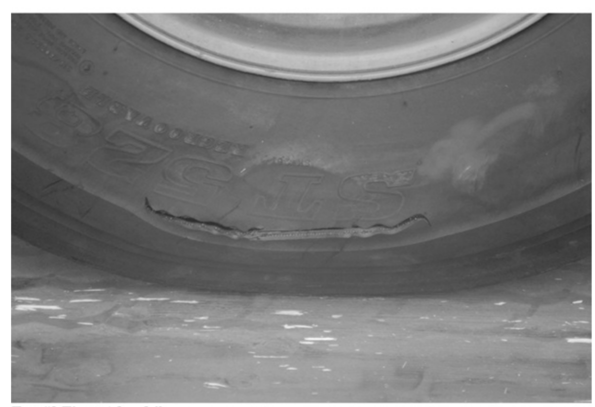
Appendix A



Appendix B



Test #1 Tire – After failure



Test #2 Tire – After failure

Appendix C

Frame 1

Frame 2

Frame 3

Frame 4

Frame 5

Frame 6

Frame 7

Frame 8

Frame 9

Frame 10

Frame 11

Test #2 Post test

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